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ULTRAVIOLET IRRADIATION TECHNIQUES TO PRESERVE MAPLE SAP

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ABSTRACT

Three methods using ultraviolet (UV) irradiation to control microbial populations in bulk-stored maple sap were studied. For 3 successive years, sap from early season, midseason, and late season sap flows was stored under the following conditions: tank No. 1, untreated control; tank No. 2, sap passed through in-line UV irradiation units before storage; tank No. 3, sap held under continuous overhead UV irradiation with agitation by stirring; and tank No. 4, sap passed through in-line UV irradiation units before storage and held under continuous overhead UV irradiation without agitation. The treatment given sap stored in tank 2 merely delayed microbial growth in the sap, but the irradiation methods used for tanks 3 and 4 gave good control of microbial populations in sap stored 5 days. Sirups made from sap stored in tanks 3 and 4 were equal in grade to sirup made from the same lot of sap before storage. Sirup made from sap stored in tank 2 was slightly lower in grade, and the sirup made from the untreated control (tank 1) was consistently darker in color and inferior in flavor.

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ULTRAVIOLET IRRADIATION TECHNIQUES

TO PRESERVE MAPLE SAP

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INTRODUCTION

Controlling microbial populations in maple sap is a major problem for the maple sirup producer. Maple sap is sterile as it flows from the tree, but it is subject to the attack of microbial contaminants from that time until it is sterilized by the atmospheric boiling process. Bacteria, yeasts, and molds can degrade sap so that sirup made from it will have off-flavors, dark color, or a ropy texture. Therefore, microbial growth must be controlled to avoid economic losses. This problem is complicated because the volume of sap produced and the duration of its flow are intermittent and unpredictable. One-third of a year's sap flow may occur in a single day, and the volume of sap produced by such a heavy flow can easily exceed the production capacity of an evaporator plant. The evaporator operator must store the raw sap so that microbial deterioration will be minimized. The development of central evaporator plants to process the sap from a large number of farms has intensified this problem.

Chemical additives cannot be used to control microbial contaminants in sap because they impart off-flavors to sirup. Also, the 35- to 40-fold concentration of sap required to produce sirup would increase chemical germicide residues to levels above those permitted by food regulatory laws. Therefore, the use of UV germicidal lamps to control microbial growth in maple sap offers a good alternative to chemical germicides. Ultraviolet rays present no residue problems and do not affect final product quality.

Initial laboratory studies that demonstrated the germicidal effects of UV rays on maple sap microorganisms were made by Naghski and Willits,[1] Frank and Willits,[2] and Schneider, Frank, and Willits.[3] The later pilot scale

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[1]/Naghski, J., and Willits, C. O. Maple Sirup. VI. The sterilizing effect of sunlight on maple sap collected in a transparent plastic bag. Food Technol. 7: 81-83. 1953.

[2]/Frank, H. A., and Willits, C. O. Maple Sirup. XIII. Sterilizing effect of sunlight on maple sap in transparent tubes. Appl. Microbiol. 8: 141-145. 1960.

[3]/Schneider, I. S., Frank, H. A., and Willits, C. O. Maple Sirup. XIV. Ultraviolet irradiation effects on the growth of some bacteria and yeasts. Food Res. 25: 654-662. 1960.

studies by Kissinger and Willits [4]/ and Kissinger, Willits, and Bell[5]/ determined that the kind of in-line UV irradiation units used to sterilize home water supplies could reduce microbial populations in sap by more than 90 percent when the sap was pumped through a UV unit at a rate of 10 g.p.m. Also, bacterial populations in small volumes (60 gal.) of stored sap could be controlled by direct overhead UV lamps, if the sap surface exposed to the germicidal rays was continually renewed by agitation.

This research was conducted to determine methods for controlling microbial populations in large volumes of stored maple sap using in-line and direct overhead UV irradiation systems.

MATERIALS AND METHODS

Tanks

Four rectangular, cylindrical-bottomed, galvanized iron tanks were installed outside the evaporator plant. Each tank was 5 feet wide, 12 feet long, and 3 1/2 feet deep at the deepest point, with a capacity of 1,137 gallons (35 barrels). Each was equipped with an opaque cover to exclude sunlight (and solar UV radiation). Two of the tanks were equipped with 30-watt tubular UV lamps mounted under the tank covers so that the entire surface of the sap stored in these tanks would be exposed to UV irradiation. Tank 3 was also equipped with a small agitator driven by an electric motor. The agitator was used to renew the surface of the stored sap continuously.

Ultraviolet Lamps

Tanks 3 and 4 were each equipped with three General Electric G30T8 UV lamps mounted in series on the lower side of the center support plank of the tank cover.

In-line Irradiation Units

Two Steroline MP2S in-line irradiation units connected in series were used to irradiate sap as it was pumped into tanks 2 and 4.

Bacterial and Yeast Counts

Bacterial and yeast counts were made using standard methods of the American Public Health Association. Media used for bacterial and yeast counts were tryptone glucose extract agar (Difco) and wort agar (Difco), respectively.

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[4]/Kissinger, J. C., and Willits, C. O. The control of microorganisms in flowing maple sap by ultraviolet irradiation. Devlpmt. Indus. Microbiol. 7: 318-325. 1966.

[5]/Kissinger, J. C., Willits, C. O., and Bell, R. A. Control of bacterial growth in stored maple sap by irradiation of the sap surface with germicidal lamps. Devlpmt. Indus. Microbiol. 10: 140-149. 1969.

EXPERIMENTAL PROCEDURE

Each storage study followed the same procedure. A 5,000-gallon lot of fresh, raw, maple sap was pumped into a bulk storage tank. After thorough mixing, 1,000 gallons of the sap was immediately converted to standard density sirup by the atmospheric boiling process. This sirup became the control for comparison with sirups made from the lots of sap stored in the four 1,000-gallon tanks. One thousand gallons of the raw sap was pumped into tank 1 (the control) and held without any treatment to inhibit microbial growth during the storage period. Tank 2 held a 1,000-gallon lot of sap that was pasteurized by passage through two Steroline in-line UV irradiation units as it was pumped into the tank at a rate of 18 g.p.m. This lot was not treated further during storage. The 1,000 gallons of raw sap pumped directly into tank 3 was not pasteurized before storage. This sap was irradiated throughout the storage period by overhead UV lamps and was agitated to renew the surface of the stored sap continuously. The final 1,000-gallon lot of raw sap was pasteurized by passage through the in-line UV units at 18 g.p.m. as it was pumped into tank 4, and then was held without agitation under the same storage conditions of direct overhead UV irradiation used for tank 3.

After 5 days of storage at ambient temperature, each lot of sap was converted to standard density sirup by the atmospheric boiling process.

Samples were taken aseptically for bacterial and yeast counts from the original 5,000 gallons of sap in the commercial tank, and from each of the four storage tanks immediately after they were filled. Also, the pH and temperature of these lots were recorded. Identical samples and measurements were taken at 24-hour intervals thereafter until the end of the 5-day storage period. Each lot of sirup was evaluated for color, flavor, and odor, and tested for pH, Brix, percent invert sugar, and percent sugar sand.

This sap storage study was made each year for 3 successive years. The studies were spaced so that early-, mid-, and late-season storage conditions could be observed during each of the three sap flow seasons.

RESULTS AND DISCUSSION

Appendix tables 1 through 9 show the data from this research.

During the three sap flow seasons studied, yeast cell counts in the raw sap were very low. The greatest yeast population was 30,000 cells per ml. in the final control tank sample taken from the late season storage study of 1965 (app. table 3). Because yeast cell counts did not provide an adequate basis for comparing the different storage procedures, they are shown only in the appendix tables. Bacterial populations of samples taken from the tanks during the three seasons varied widely with significant differences directly related to the storage methods.

Figures 1, 2, and 3 show the bacterial populations (colonies per ml.) of the sap stored for 5-day periods during the three seasons of 1965, 1966, and 1967, respectively. The bars, plotted on log scales, show the bacterial populations of samples taken at the end of the storage period, immediately

before the stored sap was converted to sirup. The grade of sirup made from each lot of sap is indicated above each bar. The bacterial populations of the original lots of sap from which the 1,000-gallon aliquots were taken for storage are shown as broken lines.

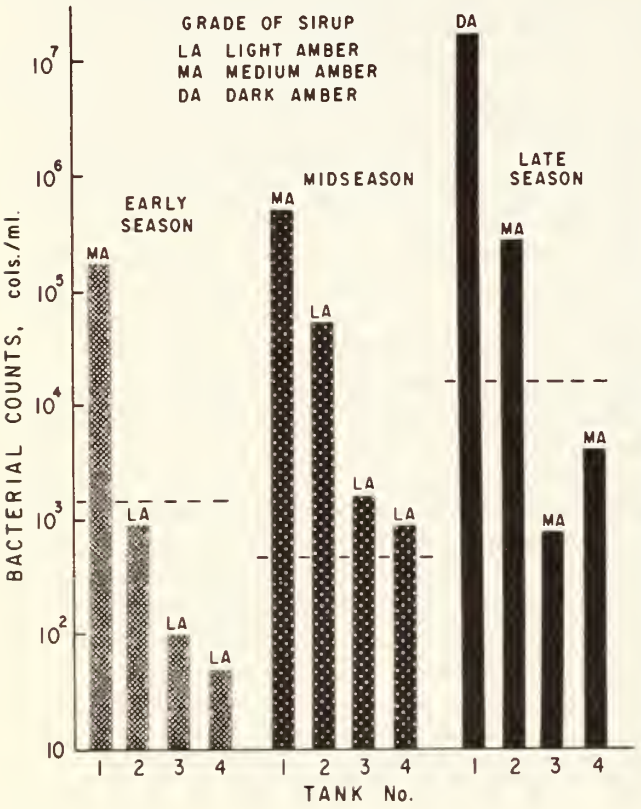

Figure 1.--Bacterial colonies per milliliter in maple sap harvested in three seasons of 1965. Dotted line shows bacterial count before storage; bars show counts at end of 5-day storage period. Tank 1, control tank (untreated sap); tank 2, sap irradiated with in-line UV lights as tank was filled; tank 3, sap irradiated continuously with overhead UV lamps and agitated; and tank 4, sap receiving combined treatments for tanks 2 and 3.

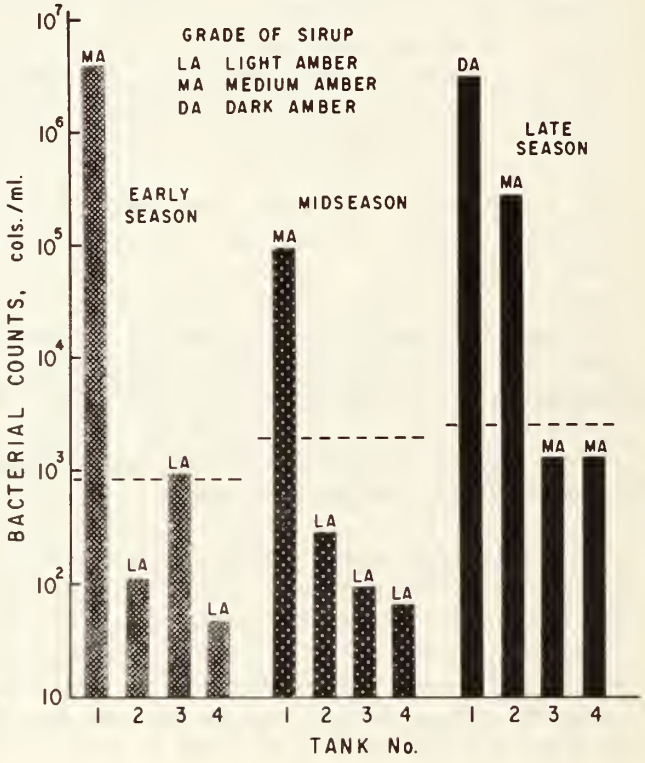

Figure 2.--Bacterial colonies per milliliter in maple sap harvested in three seasons of 1966. Dotted line shows bacterial count before storage; bars show counts at end of 5-day storage period. (See caption for figure 1 for treatments of sap in tanks 1, 2, 3, and 4.)

The final bacterial counts of samples from tank 1 (untreated control) exceeded the bacterial counts of sap held in tanks 2, 3, and 4, and sirup made from the control sap was usually one grade darker than sirup made from UV irradiated sap. In one instance (late season, 1967), a medium amber sirup was made from the control sap; dark amber sirup was made from the other lots of sap. However, the control sap had a very high bacterial population (2.2×10^7 colonies per ml.), and a low pH of 6.2. Ropiness and a bad odor developed in the sap stored in this tank, and the sirup made from it was badly off-flavored. We decided to terminate this storage study of tank 1 after 4 days. The sap lots

stored in tanks 2, 3, and 4 were held for the full 5-day storage period. These results clearly demonstrate the undesirable effect of uncontrolled bacterial growth in stored maple sap on final product quality.

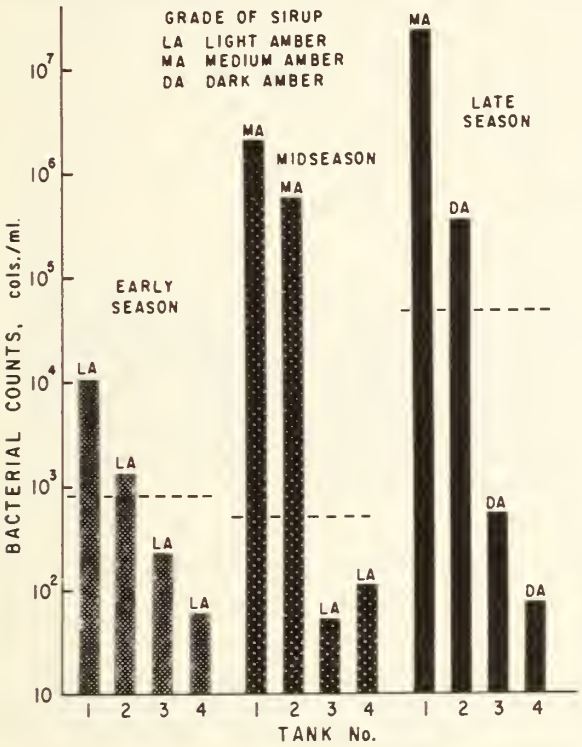

Figure 3.--Bacterial colonies per milliliter in maple sap harvested in three seasons of 1967. Dotted line shows bacterial count before storage; bars show counts at end of 5-day storage period. (See caption for figure 1 for treatments of sap in tanks 1, 2, 3, and 4.)

The sap stored in tank 2 received UV pasteurization only from the in-line irradiation units. After initial severe reductions in bacterial populations, growth took place in this sap as ambient temperatures permitted. Thus, in the early season studies, low temperatures held bacterial growth to a minimum, but during the late season studies, warmer temperatures permitted development of populations ranging from 2.8×10^5 to 3.2×10^5 colonies per ml. At the end of the storage periods, sirups made from this sap had better color and flavor than the control sirups, but the progressive increase in bacterial populations indicated that the sap would deteriorate rapidly if stored longer under these conditions.

The results of the storage methods for tanks 3 and 4 were similar. Both storage systems gave excellent control of bacterial populations in the sap throughout the study, and the bacterial populations of the stored sap exceeded those of the original commercial sap only slightly during the early 1965 and mid-1966 seasons. In the other seven storage periods, bacterial populations in the stored sap remained below those in the original lots of commercial sap. A comparison of the final bacterial counts in sap lots stored in tanks 3 and 4 does not indicate that one of these storage methods was superior to the other. In both storage tanks, bacterial growth was kept at an exceptionally low level by continuously renewing the sap surface exposed to UV irradiation by agitation and maintaining irradiation of the entire sap surface throughout the storage period, or by pasteurizing the sap with in-line UV units and then storing it under continual UV irradiation without agitation. Data in the appendix show that all sirups made from lots of sap stored in these tanks were equal in

quality (color, flavor, and odor) to sirups made from their respective original lots of sap.

Figure 4 is a graph of the early-, mid-, and late-season averages of the

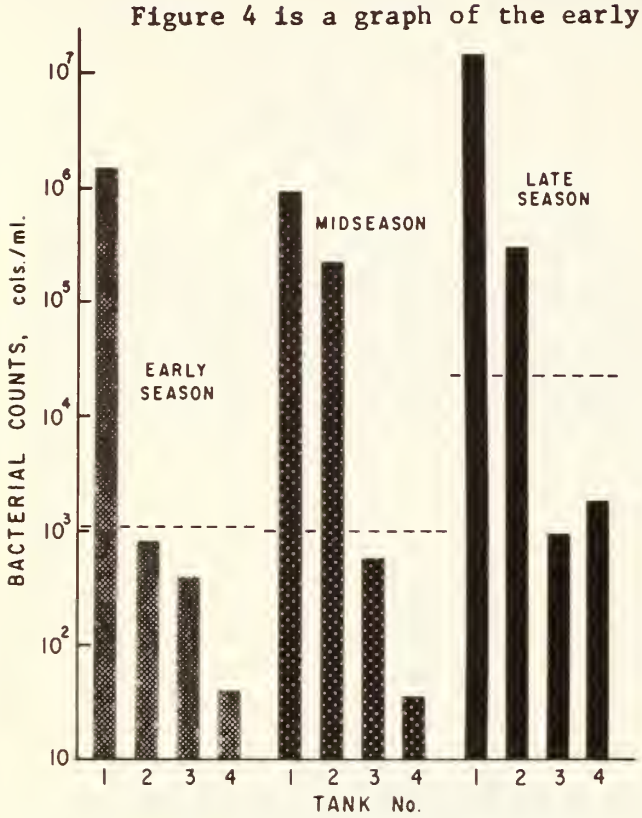

Figure 4.--Three-year seasonal averages of bacterial colonies per milliliter in stored sap. Dotted line shows bacterial count before storage; bars show counts at end of 5-day storage period. (See caption for figure 1 for treatments of sap in tanks 1, 2, 3, and 4.)

data presented in figures 1 through 3. The average bacterial populations of sap samples taken from the commercial tank were similar in the early and mid-season, 1.1×10^3 and 1.0×10^3 colonies per ml., respectively, but the late season average shows an increase in bacterial population to 2.3×10^4 colonies per ml. This increase can be attributed to several factors over which the sap producers had little or no control. Warmer seasonal temperatures, depletion of germicidal taphole pellets, and contamination of equipment that had been used since the season began with only field sanitation care, were all possible causes of the increase. The average bacterial populations of sap lots stored in tank 2 never equaled the average populations of the control (tank 1), but increased steadily from 7.8×10^2 to 2.9×10^5 colonies per ml. from early to late season storage periods. Bacterial populations of sap lots stored in tanks 3 and 4 increased slightly from early to late season, but the pasteurizing effect of the UV irradiation by overhead lamps held the population increases to a minimum. Late season average populations for tanks 3 and 4 were 8.9×10^2 and $1/8 \times 10^3$ colonies per ml., respectively, indicating that both storage methods gave excellent control of bacterial growth.

Figure 5 shows the progression of the average daily bacterial counts in sap held under the four different conditions of storage during the nine studies. The average bacterial count of the original commercial tank sap is used as the reference point, and the zero day counts are averages of samples taken when the 1,000-gallon storage tanks were filled. The bacterial population of the control tank 1 shows a typical logarithmic growth curve for sap bacteria. In

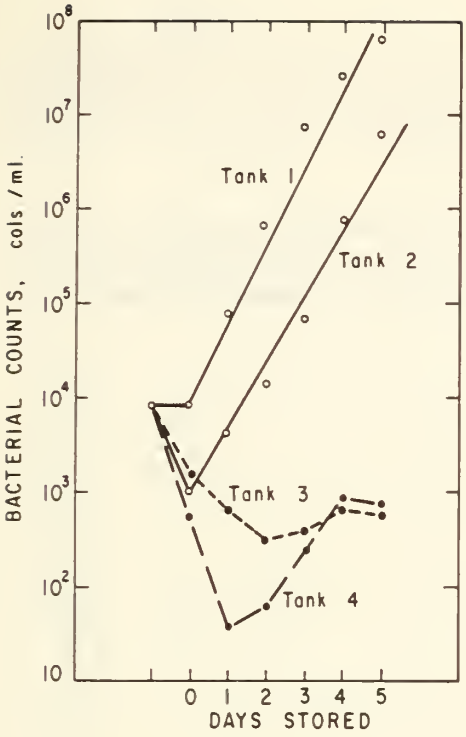

Figure 5.--Three-year averages of bacterial colonies per milliliter of sap before tanks were filled for storage tests, after tanks were filled (0 days), and in sap samples taken daily during 5-day storage period. (See caption for figure 1 for treatments of sap in tanks 1, 2, 3, and 4.)

tank 2, a similar curve is shown after the initial reduction in bacterial population caused by the pasteurization effect of the in-line irradiation units. The reduction in average bacterial counts between the commercial tank samples and the zero hour samples of tank 3 demonstrates the germicidal effect of the overhead UV lights used to irradiate the raw sap as the tank was filled, and the slightly lower average count noted for the comparable samples taken from tank 4 reflects the combined pasteurizing effect of both in-line and overhead irradiation systems during the filling operation. In tanks 3 and 4, average bacterial counts of sap samples taken at 24-hour intervals during the storage period did not show the typical logarithmic growth curve observed for bacteria in tanks 1 and 2. Instead, the storage techniques used for tanks 3 and 4 held the average bacterial counts in these tanks below 1 x 10^3 colonies per ml. The in-line UV irradiation units caused an immediate reduction in bacterial populations in sap, but gave no continuing control over the subsequent growth of the organisms that survived pasteurization. Therefore, the in-line units serve only as pasteurizers and must be augmented by other control systems for use in sap evaporator plants requiring extensive sap storage.

CONCLUSIONS

Storing raw maple sap for 5 days without controlling bacterial growth resulted in the production of sirup that was inferior in color or flavor, or both to sirup made from the same lot of fresh sap.

The initial decrease in the bacterial population of raw sap caused by pasteurization by passage through in-line UV irradiation units before storage was followed by subsequent normal, logarithmic bacterial growth in the sap during storage

The bacterial population of stored maple sap was controlled below 5 x 10^3 colonies per ml. for a 5-day storage period by irradiating the entire surface of the stored sap with direct overhead UV lamps and continuously renewing the sap surface exposed to the UV rays by agitation.

Sirups made from sap stored by the method combining direct overhead UV irradiation with continuous renewal of the sap surface (tank 3) were equal in quality to sirups made from the original commercial lots of sap.

Pasteurization of raw sap by passage through the in-line UV irradiation units before storage under direct overhead UV irradiation (tank 4) controlled bacterial growth in the stored sap as well as the method using direct overhead UV irradiation with continuous agitation.

Sirups made from sap pasteurized by passage through in-line UV irradiation units and held under direct overhead UV irradiation during storage (tank 4) were equal in quality to sirups made from the original commercial lots of sap.

Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

APPENDIX TABLE 1.--Maple sap storage--early season 1965

Tank No. and days in storage	Temp. (°F)	Yeast (colonies per ml.)	Bacteria (colonies per ml. x 10^{-3})	pH	Sirup						
					Grade	Flavor	pH	Brix	Invert sugar(%)	Odor	Sugar sand(%)
Commercial[1] 0	34	900	1	6.7	Lt. amber	Excellent	6.7	65.5	<1	None	5
Tank 1:[2]											
0	34	900	1	6.7							
1	36	200	12	6.7							
2	35	100	78	6.7							
3	36	<100	1,200	6.4							
4	34	<100	4,000	6.5							
5	36	<100	3,900	6.7	Med. amber	Good	6.5	64.6	<2	None	2
Tank 2:[3]											
0	34	40	0.22	6.7							
1	36	<1	.02	6.7							
2	35	20	.02	6.7							
3	36	<1	.03	6.7							
4	34	100	.18	6.7							
5	36	120	.13	6.7	Lt. amber	Excellent	6.9	63.0	<2	None	2
Tank 3:[4]											
0	34	550	0.16	6.7							
1	36	<1	.26	6.7							
2	35	<1	.08	6.7							
3	36	10	.15	6.7							
4	34	10	.13	6.7							
5	36	<1	1.00	6.7	Lt. amber	Excellent	6.8	66.5	<2	None	4
Tank 4:[5]											
0	34	20	<0.01	6.7							
1	36	<1	.01	6.7							
2	35	<1	.05	6.7							
3	36	20	.13	6.7							
4	34	<1	.11	6.7							
5	36	<1	.05	6.7	Lt. amber	Excellent	6.8	65.2	<2	None	5

[1] Commercial tank - Original sap before storage.
[2] Tank 1 (control).
[3] Tank 2 (U.V. lights in line).
[4] Tank 3 (lights overhead with agitation).
[5] Tank 4 (U.V. lights in line and overhead with agitation).

APPENDIX TABLE 2.--Maple sap storage--midseason 1965

Tank No. and days in storage	Temp. (°F)	Yeast (colonies per ml.)	Bacteria (colonies per ml. X 10^{-3})	pH	Sirup						
					Grade	Flavor	pH	Brix	Invert sugar(%)	Odor	Sugar sand
Commercial[1]/0	40	270	2.1	6.7	Lt. amber	Excellent	6.7	66.1	<2	None	Trace
Tank 1:[2]											
0	40	270	2.1	6.7							
1	40	760	1.6	6.7							
2	40	300	10.9	6.7							
3	36	1,200	29.6	6.7							
4	32	1,800	80.0	6.7							
5	32	800	100.0	6.7	Lt. med. amber	Excellent	6.4	66.1	<2	None	Trace
Tank 2:[3]											
0	40	270	0.01	6.7							
1	40	440	.11	6.7							
2	40	260	.11	6.7							
3	36	250	.06	6.6							
4	32	210	.07	6.7							
5	32	100	.30	6.7	Lt. amber	Excellent	6.6	66.2	<2	None	Trace
Tank 3:[4]											
0	40	430	0.21	6.7							
1	40	80	.10	6.7							
2	40	100	<.01	6.7							
3	36	100	<.01	6.7							
4	32	0	.10	6.7							
5	32	0	.01	6.7	Lt. amber	Excellent	6.7	66.0	<2	None	Trace
Tank 4:[5]											
0	40	110	0.03	6.7							
1	40	30	.03	6.7							
2	40	10	<.01	6.7							
3	36	0	<.01	6.7							
4	32	0	.03	6.7							
5	32	0	<.01	6.7	Extra lt. amber	Excellent	6.7	65.4	<2	None	Trace

[1]/ Commercial tank - Original sap before storage
[2]/ Tank 1 (control).
[3]/ Tank 2 (U.V. lights in line).
[4]/ Tank 3 (U.V. lights overhead with agitation).
[5]/ Tank 4 (U.V. lights in line and overhead with agitation).

APPENDIX TABLE 3.--Maple sap storage--late 1965

Tank No. and days in storage	Temp. (°F)	Yeast (colonies per ml. x 10^{-3})	Bacteria (colonies per ml. x 10^{-3})	pH	Sirup						
					Grade	Flavor	pH	Brix	Invert sugar(%)	Odor	Sugar sand(%)
Commercial[1] 0	37	1.2	2.7	6.7	Med. amber	Good	6.7	66.5	<2	None	2
Tank 1:[2]											
0	37	1.2	2.7	6.7							
1	51	2.2	4.7	6.4							
2	41	5.9	100.0	6.4							
3	54	11.0	1,600.0	6.7							
4	42	25.0	3,200.0	6.7		Slight					
5	40	30.0	3,300.0	6.7	Dark amber	caramel	6.5	66.4	<2	None	2
Tank 2:[3]											
0	37	0.46	.02	6.7							
1	51	.49	.10	6.4							
2	41	.75	.38	6.4							
3	54	.22	1.4	6.7							
4	42	.20	25.0	6.7							
5	40	.18	290.0	6.7	Med. amber	Good	6.5	66.2	<2	None	2
Tank 3:[4]											
0	37	1.10	2.8	6.7							
1	51	.40	2.3	6.4							
2	41	.30	.16	6.4							
3	54	.20	.72	6.7							
4	42	.18	1.2	6.7							
5	40	.01	1.4	6.7	Med. amber	Good	6.6	66.3	<2	None	2
Tank 4:[5]											
0	37	0.2	<.01	6.7							
1	51	.05	.02	6.4							
2	41	.02	.06	6.4							
3	54	.01	.93	6.7							
4	42	.03	1.5	6.7							
5	40	<.01	1.6	6.7	Med. amber	Good	6.7	66.2	<2	None	2

[1] Commercial tank - Original sap before storage.
[2] Tank 1 (control).
[3] Tank 2 (U.V. lights in line).
[4] Tank 3 (U.V. lights overhead with agitation).
[5] Tank 4 (U.V. lights in line and overhead with agitation).

APPENDIX TABLE 4.--Maple sap storage--early 1966

Tank No. and days in storage	Temp. (°F)	Yeast (colonies per ml.)	Bacteria (colonies per ml. x 10^{-3})	pH	Sirup						
					Grade	Flavor	pH	Brix	Invert sugar(%)	Odor	Sugar sand(%)
Commercial[1]/ 0	50	45	1.6	6.9	Lt. amber	Excellent	7.1	65.3	<1	None	4
Tank 1: [2]/											
0	50	45	1.6	6.9							
1	38	100	3.4	6.9							
2	35	430	59.0	6.9							
3	33	450	75.0	6.5							
4	33	500	100.0	6.5							
5	33	200	180.0	6.5	Med. amber	Good	6.4	65.2	< 1	None	Trace
Tank 2: [3]/											
0	50	10	0.01	6.9							
1	38	43	.03	6.9							
2	35	70	.06	6.9							
3	33	70	.23	6.9							
4	33	70	.25	6.8							
5	33	40	.92	6.5	Lt. amber	Excellent	7.3	65.2	< 1	None	2
Tank 3:[4]/											
0	42	25	1.0	6.9							
1	38	15	.2	6.5							
2	35	20	.02	6.9							
3	32	20	.02	6.9							
4	33	20	.01	6.5							
5	33	70	.01	6.5	Lt. amber	Excellent	7.1	65.2	<1	None	2
Tank 4:[5]/											
0	42	25	0.13	6.9							
1	38	20	.02	6.7							
2	35	20	<.01	6.7							
3	33	10	<.01	6.9							
4	33	10	<.01	6.9							
5	33	<10	<.01	6.7	Lt. amber	Excellent	7.2	65.0	<1	None	4

[1]/Commercial tank - Original sap before storage.
[2]/Tank 1 (control).
[3]/Tank 2 (U.V. lights in line).
[4]/Tank 3 (U.V. lights overhead with agitation).
[5]/Tank 4 (U.V. lights in line and overhead with agitation).

APPENDIX TABLE 5.--Maple sap storage--midseason 1966

Tank No. and days in storage	Temp. (°F)	Yeast (colonies per ml.)	Bacteria (colonies per ml. x 10^{-3})	pH	Sirup						
					Grade	Flavor	pH	Brix	Invert sugar(%)	Odor	Sugar sand(%)
Commercial[1] 0	35	70	.47	7.1	Lt. amber	Excellent	6.9	65.6	<1	None	2
Tank 1:[2]											
0	35	70	.47	7.1							
1	37	10	1.0	6.4							
2	35	10	6.1	6.4							
3	34	40	22.0	6.4							
4	35	10	350.0	6.6							
5	45	20	500.0	6.6	Med. amber	Good	6.4	62.7	<1	None	Trace
Tank 2:[3]											
0	35	30	.02	7.1							
1	37	10	.03	6.4							
2	35	10	.10	6.4							
3	34	10	3.0	6.4							
4	35	<10	11.0	6.4							
5	45	<10	49.0	6.6	Lt. amber	Excellent	6.9	66.4	<1	None	2
Tank 3:[4]											
0	35	70	.01	6.9							
1	37	30	.07	6.5							
2	35	10	.10	6.9							
3	34	10	.20	6.8							
4	35	<10	.60	6.5							
5	45	<10	1.6	6.8	Lt. amber	Excellent	6.9	65.6	<1	None	2
Tank 4:[5]											
0	35	50	.01	7.1							
1	37	50	.01	6.7							
2	35	20	.04	6.9							
3	34	10	.30	6.7							
4	35	10	.50	6.9							
5	45	<10	.85	6.9	Lt. amber	Excellent	6.9	65.6	<1	None	2

[1]/Commercial tank - Original sap before storage.
[2]/Tank 1 (control).
[3]/Tank 2 (U.V. lights in line).
[4]/Tank 3 (U.V. lights overhead with agitation).
[5]/Tank 4 (U.V. lights in line and overhead with agitation).

APPENDIX TABLE 6.--Maple sap storage--late 1966

Tank No. and days in storage	Temp. (°F)	Yeast (colonies per ml. x 10^{-3})	Bacteria (colonies per ml. x 10^{-3})	pH	Sirup						
					Grade	Flavor	pH	Brix	Invert sugar(%)	Odor	Sugar sand(%)
Commercial[1] 0	40	.25	17	6.9	Med. amber	Excellent	6.6	65.0	<1	None	6
Tank 1:[2]											
0	40	.25	17	6.9							
1	40	1.10	220	6.6							
2	41	1.70	1,200	6.6							
3	40	2.60	1,700	6.6							
4	40	2.70	3,900	6.6							
5	41	2.80	18,000	6.6	Dark amber	Good	6.5	64.8	<1	None	3
Tank 2:[3]											
0	40	.04	.2	7.0							
1	40	.07	.7	6.6							
2	41	.14	2.0	6.6							
3	40	.23	6.0	6.6							
4	40	.37	82.0	6.6							
5	41	1.4	280.0	6.6	Med. amber	Excellent	6.7	65.0	<1	None	6
Tank 3:[4]											
0	40	.02	.01	6.9							
1	40	.03	.03	6.6							
2	41	.03	.30	6.5							
3	40	.06	.40	6.6							
4	40	.36	.45	6.6							
5	41	.47	.76	6.6	Med. amber	Excellent	6.6	65.0	<1	None	5
Tank 4:[5]											
0	40	.01	.04	6.8							
1	40	.01	.20	6.6							
2	41	.02	.35	7.0							
3	40	.05	1.00	6.6							
4	40	.08	1.00	6.6							
5	41	.36	4.00	6.6	Med. amber	Excellent	6.6	64.2	<1	None	6

[1] Commercial tank - Original sap before storage.

[2] Tank 1 (control).

[3] Tank 2 (U.V. lights in line).

[4] Tank 3 (U.V. lights overhead with agitation).

[5] Tank 4 (U.V. Lights in line and overhead with agitation).

APPENDIX TABLE 7.--Maple sap storage--early 1967

Tank No. and days in storage	Temp. (°F)	Yeast (colonies per ml.)	Bacteria (colonies per ml. x 10^{-3})	pH	Sirup						
					Grade	Flavor	pH	Brix	Invert sugar(%)	Odor	Sugar sand
Commercial[1]/ 0	38	<1.0	.80	7.0	Lt. amber	Excellent	6.8	66.5	<1	None	Trace
Tank 1:[2]/											
0	38	<1.0	.76	6.9							
1	35	<1.0	1.3	7.0							
2	32[3]/	90	2.0	6.9							
3	32[3]/	520	3.0	6.9							
4	32[3]/	530	6.5	6.8							
5	32[3]/	1,000	11.0	6.8	Lt. amber	Excellent	6.9	67.3	>2	None	Trace
Tank 2:[4]/											
0	38	<1.0	0.02	6.9							
1	35	10	.08	7.0							
2	32[3]/	20	.17	6.9							
3	32[3]/	20	.33	6.9							
4	32[3]/	40	.59	6.9							
5	32[3]/	90	1.30	7.0	Lt. amber	Excellent	6.8	67.1	>2	None	Trace
Tank 3:[5]/											
0	38	<1.0	<0.01	6.9							
1	35	<1.0	.01	6.9							
2	32[3]/	<1.0	.02	6.9							
3	32[3]/	10	.04	6.9							
4	32[3]/	20	.06	6.9							
5	32[3]/	40	.22	6.9	Lt. amber	Excellent	6.8	67.3	>1	None	Trace
Tank 4:[6]/											
0	38	<1.0	<0.01	6.9							
1	35	<1.0	< .01	6.9							
2	32[3]/	<1.0	< .01	6.9							
3	32[3]/	<1.0	.01	6.9							
4	32[3]/	<1.0	.02	6.9							
5	32[3]/	17	.06	6.9	Lt. amber	Excellent	6.8	67.0	<1	None	Trace

[1]/Commercial tank - Original sap before storage.
[2]/Tank 1 (control).
[3]/Ice in tank.
[4]/Tank 2 (U.V. lights in line).
[5]/Tank 3 (U.V. lights overhead with agitation).
[6]/Tank 4 (U.V. Lights in line and overhead with agitation).

APPENDIX TABLE 8.--Maple sap storage--midseason 1967

Tank No. and days in storage	Temp. (°F)	Yeast (colonies per ml. x 10^{-3})	Bacteria (colonies per ml. x 10^{-3})	pH	Sirup						
					Grade	Flavor	pH	Brix	Invert sugar(%)	Odor	Sugar sand
Commercial[1]/ 0	50	1.2	0.5	6.9	Lt. amber	Excellent	6.6	66.9	>2	None	Trace
Tank 1:[2]/											
0	50	.17	0.5	6.9							
1	42	.18	5.1	6.9							
2	50	.70	25.0	6.9							
3	40	1.0	300.0	7.0							
4	47	1.0	1,300.0	7.0							
5	50	1.2	2,000.0	7.0	Med. amber	Excellent	6.3	66.4	>3	None	Trace
Tank 2:[3]/											
0	50	.02	.01	7.0							
1	42	.04	1.0	6.9							
2	50	.05	1.9	6.9							
3	40	.20	15.0	6.9							
4	47	.40	330.0	6.9							
5	50	1.0	570.0	7.0	Med. amber	Excellent	6.7	66.7	>3	None	Trace
Tank 3:[4]/											
0	50	<.01	<.01	6.9							
1	42	<.01	<.01	7.0							
2	50	<.01	<.01	7.0							
3	48	.01	.02	7.0							
4	47	.01	.02	6.9							
5	50	.10	.05	7.0	Lt. amber	Excellent	6.4	66.4	>3	None	Trace
Tank 4:[5]/											
0	50	<.01	<.01	7.0							
1	42	<.01	.01	6.9							
2	50	<.01	.01	6.9							
3	48	<.01	.02	7.0							
4	47	.01	.05	7.0							
5	50	.03	.13	7.0	Lt. amber	Excellent	6.5	66.4	>2	None	Trace

[1]/Commercial tank - Original sap before storage.
[2]/Tank 1 (control).
[3]/Tank 2 (U.V. lights in line).
[4]/Tank 3 (U.V. lights overhead with agitation).
[5]/Tank 4 (U.V. Lights in line and overhead with agitation).

APPENDIX TABLE 9.--Maple sap storage--late 1967

Tank No. and days in storage	Temp. (°F)	Yeast (colonies per ml. x 10^{-3})	Bacteria (colonies per ml. x 10^{-3})	pH	Sirup						
					Grade	Flavor	pH	Brix	Invert sugar(%)	Odor	Sugar sand
Commercial[1]/ 0	46	3.2	48.0	7.0	Dark amber	Fair	6.6	66.4	>2	None	Trace
Tank 1:[2]/											
0	46	.50	48.0	7.0							
1	50	3.2	370.0	7.0							
2	45	100.0	5,600.0	7.0							
3	45	100.0	12,000.0	7.0							
4	47	350.0	22,000.0	7.0	Med. amber	Poor	6.2	66.7	>3	None	Trace
Tank 2:[3]/											
0	46	.10	.20	7.0							
1	50	.60	1.0	7.0							
2	45	1.0	9.5	7.0							
3	45	1.0	25.0	7.0							
4	47	5.0	318.0	7.0	Dark amber	Fair	6.4	67.7	5	None	Trace
Tank 3:[4]/											
0	46	.72	9.0	7.0							
1	50	.33	2.5	7.0							
2	45	.18	2.0	7.0							
3	45	.3	2.0	7.0							
4	47	.2	.50	7.0	Dark amber	Fair	6.4	65.8	>4	None	Trace
Tank 4:[5]/											
0	46	.67	.39	7.0							
1	50	.41	.03	7.0							
2	45	.35	.01	7.0							
3	45	.70	<.01	7.0							
4	47	.10	<.01	7.0	Dark amber	Fair	6.6	66.3	>2	None	Trace

[1]/Commercial tank - Original sap before storage.
[2]/Tank 1 (control).
[3]/Tank 2 (U.V. lights in line).
[4]/Tank 3 (U.V. lights overhead with agiation).
[5]/Tank 4 (U.V. lights in line and overhead with agitation).

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